

## Memo

GTZ SUN: Energy , P.O. Box: 12994, Addis Ababa

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Telefax (00251-11)  
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### Re: Result of stove testing

#### Stove testing

The controlled kitchen test (CCT) and Indoor air pollution (IAP) emission monitoring test are tests that are used to get figures that shows an overview of a stove's fuel consumption and related characteristics and it's indoor air pollutants emission level respectively.

Tests conducted by the EREDPC on mirt stove showed that it has a 50% fuel saving compared to open fire stove. This was the figure that we were using so far while talking about the mirt stove. Regarding IAP measurement as there has been no test conducted so far, it was difficult to cote an exact figure about the mirt stove emission characteristics. The only point that we mentioned was its possibility of emission reduction form using of 50% less fuel. Currently the project is also engaged with designing and adoption of new cooking devices and has a final product of two injera stoves (slim mirt and approvecho) and one cooking stove (Tikikil). The main objective of designing the slim mirt stove is to reduce the material inputs which were used for producing mirt stove so as to reduce the stove cost, without compromising the performance and major benefits of the mirt stove. As there is a need to have a comparison figures of these new stove and other stoves that are promoted nationally CCTs have been conducted on open fire, mirt, SM & approvecho injera stoves and also on Tikikil cook stove (using both wood & charcoal), Lakech Charcoal stove & Traditional metal charcoal stove, while IAP tests have been done on mirt, open fire and approvecho stoves.

#### Objective:

1. To have overall comparison specific consumption figure of different biomass injera stoves like mirt, open fire, Slim Mirt (SM), and the one that is designed by Mike from Approvecho (Approvecho) stoves.
2. To have comparison figures of the modified design of Tikikil stove using wood and charcoal separately, so as to compare it with the previous test figure of the first batch of Tikikil stove and open fire using wood, and to compare efficiency of modified Tikikil stove using charcoal with lakech charcoal and traditional charcoal stoves.

3. To have a comparison figure of IAP emission using Mirt and open fire injera stoves.

### Methodology:

All comparison tests have been conducted by controlling all controllable factors that can determine the consumption as well as the emission levels. These factors which are tried to be controlled are cook, fuel type (size and moisture content) amount of batter used and kitchen type. In the case of IAP emission test it was tried to simulate real kitchen by having a certain opening like window and door and to place both monitoring devices at the same place (distance from the cook, the stove, the floor) for all tests in addition to controlling the aforementioned factors.

Same testing protocols and calculation method are using for all tests.

### Findings:

In order to get representative figure for the test result, a series of tests were conducted for each stove till we get almost consistent results. For the case of IAP measurement, eight measurements have been taken for each stove, in a controlled kitchen system.

### Controlled Cooking Test

The following two tables show the detailed comparison result and the summarised results.

**Table 1: Comparison of specific fuel consumption test results of different stoves**

Comparison between Scoria SM & Scoria Mirt						
<b>CCT results: Scoria-SM</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10640	10750	10430	10607	163
Weight of char remaining	g	760	810	1220	930	252
Equivalent dry wood consumed	g	5528	5473	5256	5419	143
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>520</b>	<b>509</b>	<b>504</b>	<b>511</b>	<b>8</b>
<b>Total cooking time</b>	<b>min</b>	<b>129</b>	<b>124</b>	<b>133</b>	<b>129</b>	<b>5</b>
<b>CCT results: Mirt scoria</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10355	10223	10125	10234	311
Weight of char remaining	g	698	1090	765	851	320
Equivalent dry wood consumed	g	5355	4924	5296	5192	386
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>518</b>	<b>481</b>	<b>523</b>	<b>508</b>	<b>45</b>
<b>Total cooking time</b>	<b>min</b>	<b>126</b>	<b>128</b>	<b>127</b>	<b>127</b>	<b>26</b>
Savings of Scoria SM over Scoria Mirt						
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>-3</b>				
	<b>%</b>	<b>-0.7</b>				
<b>Total cooking time</b>	<b>min</b>	<b>-1.7</b>				
	<b>%</b>	<b>-1.4</b>				

### Comparison between Pumice-Appr. & Scoria Mirt

<b>CCT results: Appr.-Pumice</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10180	10340	10820	10447	333
Weight of char remaining	g	440	430	460	443	15
Equivalent dry wood consumed	g	4395	4440	5200	4679	452
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>432</b>	<b>429</b>	<b>481</b>	<b>447</b>	<b>29</b>
<b>Total cooking time</b>	<b>min</b>	<b>147</b>	<b>138</b>	<b>125</b>	<b>137</b>	<b>11</b>
<b>CCT results: Mirt scoria</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10355	10223	10125	10234	311
Weight of char remaining	g	698	1090	765	851	320
Equivalent dry wood consumed	g	5355	4924	5296	5192	386
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>518</b>	<b>481</b>	<b>523</b>	<b>508</b>	<b>45</b>
<b>Total cooking time</b>	<b>min</b>	<b>126</b>	<b>128</b>	<b>127</b>	<b>127</b>	<b>26</b>

<b>Savings of Appr. Pumice over Scoria Mirt</b>		
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>60</b>
	<b>%</b>	<b>11.9</b>
<b>Total cooking time</b>	<b>min</b>	<b>-9.7</b>
	<b>%</b>	<b>-7.7</b>

### Comparison between Pumice-Appr. & Pumice SM

<b>CCT results: Appr.-Pumice</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10180	10340	10820	10447	333
Weight of char remaining	g	440	430	460	443	15
Equivalent dry wood consumed	g	4395	4440	5200	4679	452
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>432</b>	<b>429</b>	<b>481</b>	<b>447</b>	<b>29</b>
<b>Total cooking time</b>	<b>min</b>	<b>147</b>	<b>138</b>	<b>125</b>	<b>137</b>	<b>11</b>
<b>CCT results: Pumice-SM</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	11230	10370	10730	10777	432
Weight of char remaining	g	1310	800	1110	1073	257
Equivalent dry wood consumed	g	5699	5349	6128	5725	390
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>507</b>	<b>516</b>	<b>571</b>	<b>531</b>	<b>35</b>
<b>Total cooking time</b>	<b>min</b>	<b>133</b>	<b>130</b>	<b>138</b>	<b>134</b>	<b>4</b>

<b>Savings of Appr. Pumice over Scoria SM</b>		
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>84</b>
	<b>%</b>	<b>15.8</b>
<b>Total cooking time</b>	<b>min</b>	<b>-3.0</b>
	<b>%</b>	<b>-2.2</b>

**Comparison between RS-Appr. & RS SM**

<b>CCT results: Appr.RS</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10130	10220	10210	10187	49
Weight of char remaining	g	540	530	550	540	10
Equivalent dry wood consumed	g	5237	4803	5197	5079	240
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>517</b>	<b>470</b>	<b>509</b>	<b>499</b>	<b>25</b>
<b>Total cooking time</b>	<b>min</b>	<b>145</b>	<b>147</b>	<b>154</b>	<b>149</b>	<b>5</b>
<b>CCT results: R.Sand-SM</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10120	10570	10620	10437	275
Weight of char remaining	g	1250	1310	1400	1320	75
Equivalent dry wood consumed	g	5912	5884	5535	5777	210
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>584</b>	<b>557</b>	<b>521</b>	<b>554</b>	<b>32</b>
<b>Total cooking time</b>	<b>min</b>	<b>161</b>	<b>153</b>	<b>137</b>	<b>150</b>	<b>12</b>

**Savings of Appr. RS over RS SM**

<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>55</b>
	<b>%</b>	<b>10.0</b>
<b>Total cooking time</b>	<b>min</b>	<b>1.7</b>
	<b>%</b>	<b>1.1</b>

**Comparison between Pumice-Appr. & Scoria SM**

<b>CCT results: Appr.-Pumice</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10180	10340	10820	10447	333
Weight of char remaining	g	440	430	460	443	15
Equivalent dry wood consumed	g	4395	4440	5200	4679	452
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>432</b>	<b>429</b>	<b>481</b>	<b>447</b>	<b>29</b>
<b>Total cooking time</b>	<b>min</b>	<b>147</b>	<b>138</b>	<b>125</b>	<b>137</b>	<b>11</b>
<b>CCT results: Scoria-SM</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10640	10750	10430	10607	163
Weight of char remaining	g	760	810	1220	930	252
Equivalent dry wood consumed	g	5528	5473	5256	5419	143
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>520</b>	<b>509</b>	<b>504</b>	<b>511</b>	<b>8</b>
<b>Total cooking time</b>	<b>min</b>	<b>129</b>	<b>124</b>	<b>133</b>	<b>129</b>	<b>5</b>

**Savings of Appr. Pumice over Scoria SM**

<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>64</b>
	<b>%</b>	<b>12.4</b>
<b>Total cooking time</b>	<b>min</b>	<b>-8.0</b>
	<b>%</b>	<b>-6.2</b>

#### Comparison between Scoria-Appr. & Scoria SM

<b>CCT results: Appr.Scoria</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10840	10950	10720	10837	115
Weight of char remaining	g	1610	480	590	893	623
Equivalent dry wood consumed	g	3202	4567	4896	4222	899
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>295</b>	<b>417</b>	<b>457</b>	<b>390</b>	<b>84</b>
<b>Total cooking time</b>	<b>min</b>	<b>129</b>	<b>156</b>	<b>169</b>	<b>151</b>	<b>20</b>
<b>CCT results: Scoria-SM</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10640	10750	10430	10607	163
Weight of char remaining	g	760	810	1220	930	252
Equivalent dry wood consumed	g	5528	5473	5256	5419	143
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>520</b>	<b>509</b>	<b>504</b>	<b>511</b>	<b>8</b>
<b>Total cooking time</b>	<b>min</b>	<b>129</b>	<b>124</b>	<b>133</b>	<b>129</b>	<b>5</b>

#### Savings of Appr. Pumice over Scoria SM

<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>121</b>
	<b>%</b>	<b>23.7</b>
<b>Total cooking time</b>	<b>min</b>	<b>-22.7</b>
	<b>%</b>	<b>-17.6</b>

#### Comparison between Scoria-Appr. & Scoria Mirt

<b>CCT results: Appr.Scoria</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10840	10950	10720	10837	115
Weight of char remaining	g	1610	480	590	893	623
Equivalent dry wood consumed	g	3202	4567	4896	4222	899
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>295</b>	<b>417</b>	<b>457</b>	<b>390</b>	<b>84</b>
<b>Total cooking time</b>	<b>min</b>	<b>129</b>	<b>156</b>	<b>169</b>	<b>151</b>	<b>20</b>
<b>CCT results: Mirt scoria</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10355	10223	10125	10234	311
Weight of char remaining	g	698	1090	765	851	320
Equivalent dry wood consumed	g	5355	4924	5296	5192	386
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>518</b>	<b>481</b>	<b>523</b>	<b>508</b>	<b>45</b>
<b>Total cooking time</b>	<b>min</b>	<b>126</b>	<b>128</b>	<b>127</b>	<b>127</b>	<b>26</b>

#### Savings of Appr. Scoria over Scoria Mirt

<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>118</b>
	<b>%</b>	<b>23.2</b>
<b>Total cooking time</b>	<b>min</b>	<b>-24.4</b>
	<b>%</b>	<b>-19.2</b>

### Comparison between Scoria Mirt & Open fire

<b>CCT results: Mirt scoria</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10355	10223	10125	10234	311
Weight of char remaining	g	698	1090	765	851	320
Equivalent dry wood consumed	g	5355	4924	5296	5192	386
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>518</b>	<b>481</b>	<b>523</b>	<b>508</b>	<b>45</b>
<b>Total cooking time</b>	<b>min</b>	<b>126</b>	<b>128</b>	<b>127</b>	<b>127</b>	<b>26</b>
<b>1. CCT results: Open fire</b>	<b>units</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>	<b>Mean</b>	<b>St Dev</b>
Total weight of food cooked	g	10310	10233	10087	10210	217
Weight of char remaining	g	713	667	757	712	67
Equivalent dry wood consumed	g	10315	10341	10862	10506	439
<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>1001</b>	<b>1012</b>	<b>1079</b>	<b>1031</b>	<b>62</b>
<b>Total cooking time</b>	<b>min</b>	<b>117</b>	<b>125</b>	<b>123</b>	<b>121</b>	<b>6</b>

### Savings of Scoria Mirt over Open fire

<b>Specific fuel consumption</b>	<b>g/kg</b>	<b>523</b>
	<b>%</b>	<b>50.8</b>
<b>Total cooking time</b>	<b>min</b>	<b>-5.5</b>
	<b>%</b>	<b>-4.5</b>

**Table 2: Summarised comparison results**

<b>Average</b>		<b>Total cooking time (min)</b>	<b>Total weight of injera baked (gm)</b>	<b>Weight of charcoal remaining (gm)</b>	<b>Equivalent dry wood consumed (gm)</b>	<b>Specific fuel consumption (gm/kg)</b>	<b>No. of tests</b>	<b>Saving VS Open fire (%)</b>	<b>Saving VS Mirt scoria (%)</b>	<b>Saving VS S.Mirt scoria (%)</b>
<b>Slim Mirt</b>	Pumice	134	10777	1073	5725	<b>531</b>	3	48.5	-4.5	-3.9
	Scoria	129	10607	930	5419	<b>511</b>	3	50.4	-0.6	0.0
	R.Sand	150	10437	1320	5777	<b>554</b>	3	46.3	-9.1	-8.4
<b>Approvecho</b>	Pumice	137	10447	443	4679	<b>447</b>	3	56.6	12.0	12.5
	Scoria	151	10837	893	4222	<b>390</b>	3	62.2	23.2	23.7
	R.Sand	149	10187	540	5079	<b>499</b>	3	51.6	1.8	2.3
<b>Mirt-Scoria</b>	Pumice									
	Scoria	127	10234	851	5192	<b>508</b>	10	50.7		0.6
	R.Sand									
<b>Open fire</b>		121	10210	712	10506	<b>1031</b>	9			

As it is seen in the above table, slim mirt and mirt have almost the same saving which is about 0.6% better saving for the mirt stove. The approvecho stove has better saving both cases with 23.2% and 23.7% better saving compared to the scoria mirt stove and scoria slim mirt stove respectively.

When we see the saving of the stoves over open fire, 62.2 %, 50.7% and 50.4% of saving was

exhibited for the scoria-aprovecho, scoria mirt and scoria slim mirt respectively. Here we take the scoria stoves figure because we have managed to do the tests on the scoria stoves of all types of stoves. One point that has been noticed during the test of the slim mirt is the importance of having frequent maintaining of the stove on its part where the mitad lies because it doesn't have the shoulder part unlike the ordinary mirt stove and the mud that is used to plaster it was easily dried and crumble out due to exposure of the fire (see picture 1). This issue should have been discussed thoroughly with the users as there might be a problem on doing frequent maintenance of this part.



Picture 1: Mirt and Slim mirt stove

#### Sheer weight of tested injera stoves and their comparison figures

Slim Mirt weight (kg)		Wall 1	Wall 2	Wall 3	Wall 4	pot rest	Big U	Small U	Total		Material saving in % (BU-SM Vs Std. Mirt)	Material saving in % (SU-SM Vs Std. Mirt)	Material saving in % (SM Vs Approvecho)
									with BU	with SU			
Scoria		5.86	5.63	5.82	5.84	7.7	7.33	0.52	38.18	31.37	45	55	18
Pumice		4.67	4.29	4.24	4.35	5.56	4.9	1.82	28.01	24.93	57	62	15
River Sand		6.82	6.91	6.77	6.45	9.25	8.64	2.96	44.84	39.16	40	48	6

Mirt stove weight (kg)		Left Fuel inlet	Right Fuel inlet	Left chimney	Right chimney	Pot rest	U shape	Total
Scoria		9.76	9.69	10.09	10.83	12.45	16.96	69.8
Pumice								65
River Sand								75

Approvecho's stove weight (kg)		Channel Circle 1	Channel Circle 2	Support 1	Support 2	Combustion Chamber 1	Combustion Chamber 2	Total	Material saving in % (Std. Mirt)
Scoria		11.04	11.3	6.98	7.23	4.95	5	46.5	33
Pumice		8.45	7.51	4.84	4.72	3.68	3.62	32.8	50
River Sand		10.88	12.09	7.42	6.85	5.3	5.08	47.6	37

## IAP results

As it has been explained in the previous part of the report, the IAP measurement was taken for 8 consecutive tests for each stove (mirt, open fire & approvecho stoves). In each test it was tried to control all controllable factors. The only variable that was existed was the stove itself. All stoves were installed at the same place in the kitchen. The positions of the monitoring devices (UCB for measuring particulate matter and HOBO for measuring carbon monoxide concentration) were also the same through out the tests.

## Findings

As the measurement was configured so as to measure the 8 hrs concentration of CO and particulate matters concentration in the kitchen, in order to analyse the figure the data of the baking period plus 5 minutes before starting the baking and 30 minutes after finishing the baking were considered for the case of analysing CO concentration & the data of the baking period plus 5 minutes before starting the baking and 15 minutes after finishing the baking for the case of analysing particulate matter concentration (as after 15 minutes it was almost zero in most cases).

### CO emission concentration for baking injera (ppm)

Test no.		Mirt stove			Open fire stove			Approvecho stove		
		C1	C2	C3	C1	C2	C3	C1	C2	C3
	Average	7.41	7.95	6.75	67.55	70.92	68.59	6.96	7.12	6.89
1	Average of the Baking session	6.94	7.46	6.30	71.24	73.79	71.28	6.31	6.55	6.54
	Max. value	37.40	38.10	35.00	124.30	186.50	184.00	79.30	79.10	74.00
	Average	23.44	24.60	24.44	82.48	99.21	98.20	10.21	10.47	8.39
2	Average of the Baking session	28.16	29.39	28.87	96.82	117.46	116.20	9.56	9.75	7.58
	Max. value	76.90	79.10	74.00	124.30	260.70	262.00	45.70	45.90	43.00
	Average	7.75	8.29	7.67	83.49	93.94	91.34	0.42	5.63	5.72
3	Average of the Baking session	7.84	8.41	7.75	94.44	106.34	103.47	5.60	5.60	5.29
	Max. value	36.40	38.10	35.00	124.30	229.50	223.00	38.30	38.10	35.00
	Average	1.27	2.36	4.41	62.21	64.39	63.74	14.33	14.52	12.41
4	Average of the Baking session	1.49	2.65	4.53	69.19	70.55	69.70	15.25	15.34	13.00
	Max. value	10.50	12.70	12.00	124.30	178.70	176.00	52.50	51.80	51.00
	Average	1.96	2.68	4.76	71.69	79.34	77.24	6.91	6.93	6.30
5	Average of the Baking session	0.45	1.22	4.00	79.19	87.82	85.57	5.04	5.08	4.76
	Max. value	40.80	42.00	35.00	124.30	252.90	254.00	44.20	43.90	43.00

Test no.		Mirt stove			Open fire stove			Approvecho stove		
		C1	C2	C3	C1	C2	C3	C1	C2	C3
	Average	1.24	2.32	4.40	88.01	107.85	106.68	10.03	10.20	7.44
6	Average of the Baking session	1.48	2.62	4.51	100.40	123.27	121.86	11.36	11.46	8.43
	Max. value	10.50	12.70	12.00	124.30	249.00	246.00	26.60	26.40	20.00
	Average	1.54	2.24	4.46	92.93	115.50	112.78	4.65	4.91	5.54
7	Average of the Baking session	0.54	1.31	4.00	104.37	126.07	123.22	2.54	2.85	4.29
	Max. value	35.90	36.10	35.00	124.30	313.50	309.00	31.50	32.20	27.00
	Average	4.13	5.33	6.86	83.49	94.55	93.15	13.42	13.39	10.45
8	Average of the Baking session	1.98	3.11	4.64	95.11	103.19	101.54	13.96	13.90	10.72
	Max. value	94.00	96.70	98.00	124.30	264.60	262.00	28.10	28.30	27.00
	Average	6.09	6.97	7.97	78.98	90.71	88.97	8.37	9.14	7.89
Average	Average of the Baking session	6.11	7.02	8.08	88.84	101.06	99.11	8.70	8.82	7.58
	Max. value	42.80	44.44	42.00	124.30	241.93	239.50	79.30	79.10	74.00
		Mirt stove		Approvecho stove						
Emission reduction over open fire		%		%						
Average		92.28		89.41						
Average of the Baking session		93.12		90.21						
Max. value		82.31		67.22						

Table 1: Comparison of CO concentration

## Particulate matter emission concentration (mg/m<sup>3</sup>)

### Particulate matter emission concentration using Open fire for baking injera (mg/m<sup>3</sup>)

	1	2	3	4	5	6	7	8	Overall average
Average	0.80	0.67	0.84	1.09	0.83	0.60	2.02	0.97	<b>0.98</b>
Average of the Baking session	0.92	0.66	0.83	1.21	0.76	0.66	2.19	1.10	<b>1.04</b>
Maximum	6.42	8.17	6.03	8.03	6.03	4.56	27.62	4.39	<b>8.91</b>

### Particulate matter emission concentration using mirt for baking injera (mg/m<sup>3</sup>)

	1	2	3	4	5	6	7	8	Overall average	Emission reduction over open fire (%)
Average	0.55	2.18	0.95	0.54	0.12	0.48	0.41	0.24	<b>0.68</b>	<b>30</b>
Average of the Baking session	0.55	2.50	1.09	0.62	0.13	0.60	0.45	0.24	<b>0.77</b>	<b>26</b>
Maximum	9.31	14.60	12.74	3.70	2.73	2.22	5.67	1.46	<b>6.55</b>	<b>26</b>

### Particulate matter emission concentration using approvecho for baking injera (mg/m<sup>3</sup>)

	1	2	3	4	5	6	7	8	Overall average	Emission reduction over open fire (%)
Average	0.32	0.19	0.22	0.43	0.28	0.25	0.17	2.23	<b>0.51</b>	<b>48</b>
Average of the Baking session	0.35	0.20	0.27	0.45	0.34	0.23	0.21	3.80	<b>0.73</b>	<b>30</b>
Maximum	7.24	2.17	2.27	3.50	3.03	1.73	1.57	7.24	<b>3.60</b>	<b>60</b>

**Table 2: Comparison of particulate matter concentration**

The above tables show the comparison figures for both CO as well as particulate matter concentration of all the three tested stoves. The average figures of table 1 shows that about 90% and 83% of reduction of CO over open fire for mirt and approvecho stoves respectively and table 2 shows that about 27% and 46% of particulate matter reduction over open fire for mirt and approvecho stoves respectively.

## Water boiling test on Tikikil stove

Water boiling test was conducted to get a comparison consumption figure of open fire, the first very version of Tikikil & the new version of Tikikil stoves. The first version of Tikikil stove had a square shape and had no metal liner while the new one has a circular shape and also with a circular metal liner that has a grate in order to be used for burning charcoal too. Therefore the latest version of tikikil was also tested using charcoal, so as to look at its consumption in comparison to other charcoal stoves.

## Findings

The following tables show the summary of the result.

**Table 1: Summary of WBT test result using wood**

Stoves/test results	Time for boiling (min)	Energy input (kJ)	Energy output (kJ)	Power input (kw)	Power output (kw)	Eff. (%)	Amount of water boiled (kg)	Fuel used per kg of water boiled (kg)	Saving over open fire (%)	Saving over old Tikikil (%)	Time saving over open fire (min)	Time saving over old Tikikil (min)
Open fire	44.50	26199.48	3760.20	4.18	0.60	14.35	1.15	1.20				
Square tikikil without liner	23.03	13499.88	3450.49	2.71	0.69	25.56	1.02	0.70	42		21.47	
Circular Tikikil with liner (new)	18	14779.45	4922.57	3.17	1.06	33.32	1.65	0.48	60	31.78	26.50	5.03

**Note:** the open fire and the Square tikikil stove test results are taken from previous tests conducted in the office.

**Table 2: Summary of WBT test result using charcoal**

Stoves/test results	Time for boiling (min)	Energy input (kJ)	Energy output (kJ)	Power input (kw)	Power output (kw)	Eff. (%)	Amount of water boiled (kg)	Fuel used per kg of water boiled (kg)	Saving over Traditional metal charcoal stove (%)	Time saving over Traditional metal charcoal stove (min)
Traditional metal charcoal stove	31	14886.67	3368.48	2.74	0.62	23	0.95	0.55	0	
Lakech charcoal stove	32	11020.00	4198.81	2.00	0.76	38	1.33	0.29	47	-1.67
Circular Tikikil with liner (new)	42	10440.00	3075.79	1.70	0.50	30	0.83	0.44	20	-11.67

In the table 1, the results taken for the square tikikil version and the open fire are from tests that have been conducted when the design of the Tikikil stove was at its infant stage. It was only one test conducted for each stove and the amount of water used for the test was 3.8 kg. However, in the test of Tikikil new, the amount of water used was 4 kg and the average of three tests under the same condition is taken as an average result. To get the exact comparison figure it is important to do the same number and kinds of test for the open fire and the square tikikil version though this one can be used as an indicative.

Test results of the wood burning stove (table 1) indicate that the Circular Tikikil (new version) has better fuel saving by 80% and faster by 26.5 minutes compared to open fire (without forgetting the

3.8 kg and 4 kg. of water used for open fire and Tikikil stove respectively). Even compared to the first version of Tikikil stove it has better fuel saving of 32% and time saving by 5.03 minutes.

In the table 2, the average of three tests is taken for all kinds of stoves that are being compared. And all tests were done under the same condition and using the same protocol.

Test results of the charcoal stoves (Table 2) show that the Circular Tikikil (new version) has better fuel saving of 20% compared to the Traditional Metal Charcoal Stove while Lakech Charcoal stove saves charcoal by 47% compared to Traditional Metal Charcoal Stove. Looking at the time taken to boil equal amount of water the Circular Tikikil (new version) used 11.67 more minutes while Lakech Charcoal Stove used 1.67 more minutes compared to the Traditional Metal Charcoal Stove. However, though using of Circular Tikikil makes the cooking process slower for the case of using charcoal, its fuel saving (in both cases of using fuelwood as well as charcoal) and its multi fuel usage characteristics makes the stove acceptable and ready for the market.

**Reported by:**

Hiwote Teshome